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Original Article

Phytosociology of floristic groups in subtropical seasonal forests in the south extreme of the Atlantic Forest Biome

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Abstract
This study aimed to differentiate the structure and flora of tree component groups of a forest fragment in the South of Atlantic Forest Biome. For sampling the tree layer (diameter at breast height ≥ 5.0 cm), 18 plots of 20 m × 10 m were systematically installed. Data were analyzed according to the structure and diversity of vegetation using the agglomerative hierarchical cluster analysis method with Ward linkage, and the quadratic Euclidean distance to measure dissimilarity. The formation of three groups of flora was evident. The species composition of each group belonged to different stages of natural succession. Group I had the highest species richness (42 species) and the highest species diversity (2.92 nats.ind.$^{-1}$). The species with the highest importance value index (VI) were: in Group I, *Actinostemon concolor* (14.7%), *Trichilia claussenii* (VI = 9.8%) and *Apuleia leiocarpa* (8.9%); in Group II, *Trichilia claussenii* (21.2%), *Sorocea bonplandii* (18.1%) and *Trichilia elegans* (17.6%); and in Group III, *Allophylus edulis* (12.1%), *Cupania vernalis* (9.6%) and *Trichilia claussenii* (9.4%). The three groups showed a negative exponential diameter distribution, common in forests with auto-regeneration capacity. Thus, the group 1 has the highest values of diversity and number of species between the groups and the highest floristic similarity with the forest in general, being considered the closest representative of the floristic composition of the forest remnant Subtropical Seasonal Forests evaluated.
Keywords: Cluster analysis, Ecological groups, Forest succession.

Introduction

Subtropical seasonal forests present great floristic diversity, attributed mainly to the climate and soil conditions of the regions where they occur (Almeida et al. 2015). This forest formation is found in the Atlantic Forest Biome and its characterized as the most threatened and the least protected biome of the Atlantic Forest in the south of Brazil, mainly due to the fact that it occupies less than 4% of its original area (IBGE 1990).

The fragmentation and reduction of the coverage of the remnants of the subtropical seasonal forest in this biome is associated with the advancement of agriculture and livestock farming, as well as the intensive exploitation of timber species, which compromises the biological diversity and conservation of these environments. As such, highlights the importance of detailed studies of the remaining forest formations, aiming to enable the conservation of these vegetal communities and provide information on the restoration of altered environments, using material that represents the local diversity. However, this requires knowledge about the involved plant populations and, consequently, the community as a whole (Almeida et al. 2015).

The understory, in particular, is the most sensitive stratum to environmental disturbances, such as formation of clearings, that change the microclimate of the forest, increasing the incidence of light and hydric stress (Poorter et al. 2006) on young individuals that are sensitive to changes in the conditions of the site (Holz et al. 2009). In this way, identifying species that share environmental affinities and usually occupy the same places in the overall landscape in predictable relative proportions, can be used to indicate environmental complexes (Goebel et al. 2001; Adel et al. 2014). Thus, performing phytosociological studies allows us to obtain information about the ecological processes, regarding the characteristics and permanent and continuous transformations that occur in several ecological environments (Queiroz et al. 2001).

In this sense, the present study aimed to identify and describe the structure and floristic composition in relation to different histories of soil use of a remnant of Subtropical Seasonal Forest in the Atlantic Forest Biome in the extreme south in the Rio Grande do Sul State, Brazil.

Material and Methods

The research was carried out in a forest remnant (29°27′14.71″S 53°18′17.86″W) of approximately 20 hectares, located in the extreme south of the Atlantic Forest Biome, in Nova Palma, Rio Grande do Sul (Figure1).

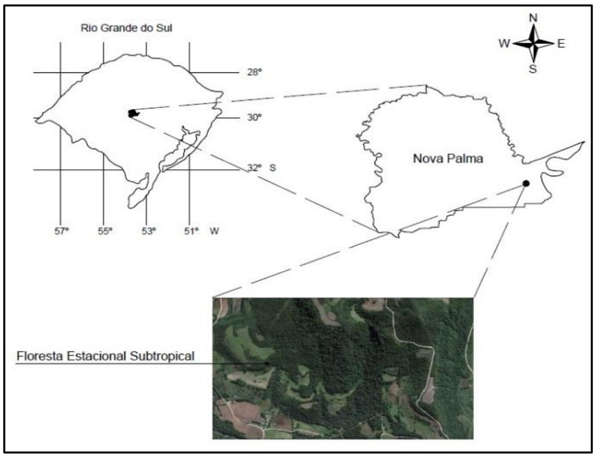

Figure 1. Geographical location of the study area, Nova Palma, Rio Grande do Sul State, Brazil, 2015.

The soil of the study area is classified as Regolithic Neosol (EMBRAPA 2009). The climate, according to Köppen's classification is "Cfa," with an annual average precipitation between 1400 and 1760 mm, and temperatures between -3 and 30°C (Alvares et al. 2013).

The studied forest remnant belongs to Subtropical Seasonal Forest (Schumacher et al. 2011), with vegetation considered to be almost exclusive to the basins of the rivers Jacuí, Ibicuí, Santa Maria and Uruguai (Veloso et al. 1992). The region has elevated declivity and was colonized by Italian immigrants in 1877, who used the areas for agriculture and livestock farming, which caused changes in the landscape through wood exploitation and exclusion of forests (Itaqui 2002).

For the vegetation survey, the study area was demarcated into 18 plots of 10 m × 20 m, distributed in a systematic way in four equidistant 50 m transects of variable length to accommodate the limits of the forest. In each plot, individual trees measuring a diameter at breast height (DBH) ≥ 5 cm were identified.

For species that were not identified on site, botanical material was collected and later evaluated by consulting the bibliography and/or with the help of specialists. The species were classified into the botanical families recognized by the Angiosperm Phylogeny Group III (APG III 2009).

For the cluster analysis, the number of individuals of the species in each plot were considered. The data generated a matrix showing plot × species, with 18 plots (rows) and 56 species (columns). Afterwards, the plots were clustered using the agglomerative hierarchical cluster method with Ward linkage. To measure dissimilarity, the quadratic Euclidean distance was used and data were processed using the Statistical Package for Social Science for Windows software program (SPSS) 13.0 (SPSS 2004). The attributes indicative of each cluster were compared by Kruskal-Wallis non parametric test.

The sampled species were classified into ecological groups according to Budowski (1965), as pioneer (P), initial secondary (IS) and late secondary (LS). The classification was carried out through field observations and bibliographic review (Vaccaro et al. 1999).

It was analyzed the floristic structure for each cluster. The floristic structure was described using Shannon's diversity index (H') and Pielou's equitability index (J), and by calculating the horizontal structure using the parameters density, frequency, dominance and importance value (Felfili and Rezende 2003). Individual specimens were classified by classes of diameter with intervals of 10 cm.

Results and Discussion

By means of the cluster analysis, the formation of three distinct groups was identified, differentiated by the history of the area. Cluster I, formed by eight plots, had greater occurrence in an area with a recent history of occupation by cattle; Cluster II, with four plots, occurred in an area with greater declivity in the eastern parts; and Cluster III, with six plots, was the most representative of an area that had experienced selective exploitation approximately 20 years ago (Figure 2). This indicates that the forest has a heterogeneous composition (Callegaro et al. 2014) as was detected in other areas in the same phytogeographical unit of Subtropical Seasonal Forest (Almeida et al. 2015; Callegaro and Longhi 2013; Marcuzzo et al. 2013).

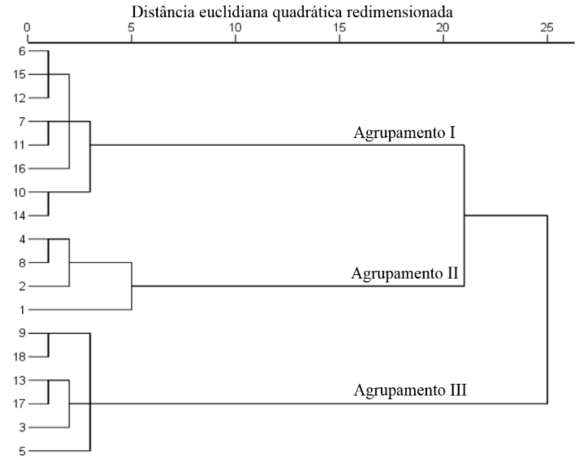

Figure 2 - Dendrogram of floristic similarity among plots of a remnant of Subtropical Seasonal Forest in the extreme South of Atlantic Forest Biome, 2015.

In relation to floristic structure, in Cluster I, 163 individuals were observed (1032 trees.ha^{-1}), belonging to 42 species and 18 botanical families. In Cluster II, 104 individuals were sampled (650 trees.ha^{-1}), belonging to 18 species and 12 botanical families. In Cluster III, 171 individuals were obtained (1068 trees.ha^{-1}), distributed amongst 32 species and 12 botanical families. Across the three clusters, 25 botanical families and 55 species were found (Table 1).

Table 1 - Floristic and phytosociological attributes of clusters of a remnant of Subtropical Seasonal Forest in the South of Atlantic Forest Biome, 2015.

	Cluster I	Cluster II	Cluster III	Kruskal-Wallis	
				H	*p**
Density (trees.ha^{-1})	1032	1287	1424	4.34	0.034
Nº of species	42	18	32	5.34	0.002
Nº of families	17	12	12	0.57	0.234
Index of Shannon-Wiener (*S'*)	2.92	1.86	2.35	6.48	0.001
Equability of Pielou (*J*)	0.78	0.64	0.68	2.56	0.045

H: Statistical non-parametric test Kruskal-Wallis; *p*: probability obtained in the test; *: values lower than 0.05 indicate significant differences.

The floristic diversity was superior in Cluster I (*S'* = 2.92 nats.ind.$^{-1}$; *J* = 0.78) compared to Cluster II (*S'* = 1.89 nats.ind.$^{-1}$; *J* = 0.64) and Cluster III (*S'* = 2.35 nats.ind.$^{-1}$; *J* = 0.68). Cluster I and the forest in general (*S'* = 3.07 nats.ind.$^{-1}$; *J* = 0.69) presented diversity and equitability similar to that estimated by Marcuzzo et al. (2013) (*S'* = 3.00 nats.ind.$^{-1}$; *J* = 0.78) in analyzing floristic groups in a fragment of subtropical seasonal forest, by Kilca and Longhi (2011) in secondary forests on the edge of Brazilian southern plateau (*S'* = 3.08 nats.ind. $^{-1}$; *J* = 0.82) and by Turchetto et al. (2015) in a Deciduous Seasonal Forest in the northeast of the state (*S'* = 2.97 nats.ind^{-1}; *J* = 0.70).

The higher values of diversity in class I are related to the highest occurrence of late secondary species is attributed to Cluster I (Table 2), indicating that this cluster presents a structure more similar to a primary forest and therefore, it is designated as such. In contrast, Cluster III shows evidence of a greater presence of initial secondary species, which indicates an environment in formation, with greater entrance of light in the lower strata of the forest, a factor that contributes to the regeneration of pioneer and initial secondary species. According to Vaccaro et al. (1999) there is substitution of the successional categories as the process of succession evolves, when the late secondary species start to have a fundamental function in the community.

It can be verified that the difference in richness between the remnants are related mainly to the time since the last intervention. Natural disturbance or anthropogenic disturbance may affect the diversity and composition of species in the lower story in different forests (Lin and Cao 2009; Rasingam and Parthasarathy 2009), which can have great implications for the succession, dynamics and function of the ecosystem (Royo and Carson 2006).

In relation to the phytosociological parameters, the species that presented the greatest values of importance in Cluster I were *Actinostemon concolor* (Spreng.) Müll. Arg. (14.7%), *Trichilia claussenii* C. DC. (9.8%), *Apuleia leiocarpa* (Vogel) J.F.Macbr (8.9%), *Trichilia elegans* A. Juss. (8.2%) and *Erythrina falcata* Benth. (6.4%), representing 48% of the horizontal structure of the group. In Cluster II, the most representative species were *T. claussenii* (21.2%), *Sorocea bonplandii* (Baill.) W.C Burger, Lanjouw & Boer (18.1%), *T. elegans* (17.6%), *Citronella gongonha* (Mart.) R. A. Howard (8.6%) and *A. concolor* (7.3%), representing 72.8% of the structure of the forest. For Cluster III, the species better ranked were *Allophylus edulis* (A. St.-Hil., Cambes. & A. Juss.) Radlk. (12.1%), *Cupania vernalis* Cambess. (9.6%), *T. claussenii* (9.4%), *Nectandra megapotamica* (Spreng.) Mez (8.7%) and *Parapiptadenia rigida* (Benth) Brenan (4.3%), which made up 44.1% of the horizontal structure, thus characterizing the group under study (Table 2).

In Cluster III, the main species were initial secondaries whereas in Clusters I and II, there was a predominance of late secondary species. This pattern was also evinced by Callegaro et al. (2014), who verified that the differentiation of the arboreal community of clusters in a Deciduous Seasonal Forest in Parque Estadual da Quarta Colônia, Rio Grande do Sul (Quarta Colônia State Park) was a function of the demand for light by the species.

Table 2 - **S**tructural parameters of clusters of a forest remnant in the South of Atlantic Forest Biome.

Species	Cluster I		Cluster II		Cluster III		EG
	AD	IIV	AD	IIV	AD	IIV	
Actinostemon concolor (Spreng.) Müll.Arg.	516.7	14.7	137.5	7.3	37.5	2.2	LS
Aiouea Saligna Meisn.					8.3	0.3	LS
Albizia niopoides (Spruce ex Benth.) Burkart	6.3	0.7					IS
Alchornea triplinervia (Spreng.) M. Arg.	6.3	0.7	12.5	1.8			IS
Allophylus edulis (A.St.-Hil., Cambess. & A. Juss.) Radlk.	16.7	1.2			56.3	12.1	IS
Apuleia leiocarpa (Vogel) J.F.Macbr.	37.5	8.9	25.0	2.1	16.7	1.9	LS
Balfourodendron riedelianum (Engl.) Engl.	6.3	0.6			8.3	0.3	LS
Banara tomentosa Clos	12.5	1.3	12.5	2.2	8.3	0.3	LS
Bauhinia forficata Link			12.5	1.5			IS
Cabrailea canjerana (Vell.) Mart.	25.0	1.9	25.0	3.7	16.7	0.8	IS
Campomanesia guazumifolia (Cambess.) O.Berg.	12.5	1.4			8.3	0.2	IS
Campomanesia xanthocarpa O.Berg	50.0	3.7			8.3	0.4	LS
Casearia decandra Jacq.	6.3	0.6			6.3	0.6	IS
Casearia sylvestris Sw.					16.7	0.9	IS
Cedrela fissilis Vell.	18.8	4.2			8.3	2.1	IS
Chrysophyllum gonocarpum (Mart. & Eichler) Engl.	6.3	0.6					LS
Chrysophyllum marginatum (Hook. & Arn.) Radlk.	6.3	0.6					LS
Citronela gongonha (Mart.) R.A.Howard			12.5	8.7			LS
Cordia americana (L.) Gottshling & J.E.Mill.	37.5	4.8			8.3	2.3	IS
Cordia ecalyculata Vell.			12.5	1.5	8.3	2.1	IS
Cordia trichotoma (Vell.) Arrab. ex Steud.					8.3	2.1	IS
Cupania vernalis Cambess.	18.8	1.9	37.5	2.8	91.7	9.6	IS
Dalbergia frutescens (Vell.) Britton			12.5	1.5			IS
Erythrina falcata Benth.	18.8	6.4					LS
Eugenia involucrata DC	6.3	0.7			8.3	1.7	IS
Eugenia rostrifolia D.Legrand	6.3	0.6			25.0	2.1	IS
Eugenia uniflora L.	6.3	0.6					LS
Ficus luschnathiana (Miq.) Miq.	6.3	0.7			8.3	3.2	IS
Inga marginata Willd.	6.3	0.7					P
Inga vera Willd	6.3	0.6			9.3	1.2	P
Jacarandá micrantha Cham.	6.3	0.1					IS
Lonchocarpus campestris Mart. ex Benth.	6.3	0.6			16.7	0.6	NC
Luehea divaricata Mart. & Zucc.	6.3	1.4					IS
Machaerium paraguariense Hassl.	18.8	2.6					IS
Maclura tinctoria (L.) Don ex Steud.	6.3	0.8					IS
*Matayba elaeagn*oides Radlk.	18.8	3.1					IS
Maytenus aquifolia Mart			12.5	1.5			LS
Myrcianthes pungens (O.Berg) D. Legrand					16.7	3.1	LS

Myrocarpus frondosus Allemão					16.7	2.7	IS
Nectandra megapotamica (Spreng.) Mez	6.3	1.1	12.5	1.5	25.0	8.7	IS
*Ocotea puberul*a (Rich.) Nees	12.5	3.0			16.7	2.5	IS
Parapiptadenia rigida (Benth.) Brenan	25.0	4.1			25.0	4.3	P
Phytolacca dioica L.			12.5	1.6			IS
Picrasma crenata (Vell.) Engl.					6.3	0.6	LS
Prunus myrtifolia (L.) Urb					8.3	3.8	IS
Ruprechtia laxiflora Meisn.					6.3	0.6	IS
Schaefferia argentinensis Speg					8.3	0.7	IS
Schefflera morototoni (Aubl.) Maguire, Steyerm. & Frodin	6.3	0.6			6.3	0.6	IS
Sebastiania brasiliensis Spreng	6.3	0.7					IS
Sebastiania commersoniana (Baill.) L.B. Sm. & Downs	6.3	0.7	12.5	2.1	8.3	0.4	IS
Sorocea bonplandii (Baill.) W.C. Burger, Lanjouw & Boer	75.0	5.5	287.5	18.1	16.7	3.5	LS
Syagrus romanzoffiana (Cham.) Glassman	6.3	0.6			108.3	3.4	P
Trichilia claussenii C.DC.	262.5	9.8	562.5	21.3	275.0	9.4	LS
Trichilia elegans A. Juss.	143.8	8.2	87.5	17.6	83.3	2.3	LS
Zanthoxylum rhoifolium Lam.					8.3	0.9	IS
Sum	1032	100	1287	100	1424	100	

In which: IIV = value of importance; EG = ecological groups; AD = Absolute density (trees.ha^{-1}).

Analysis of the three clusters indicates that the diametrical distribution (Figure 3) has a tendency towards a negative exponential, thus confirming the characteristic standard of natural forests (Imaña-Encinas et al. 2008). Furthermore, according to Souza et al. (2012) this indicates that the forest has a capacity for resilience regarding the balance between the recruitment and mortality rates. This standard of distribution has, as a main characteristic, a greater number of individuals in the first classes of diameter (Callegaro et al. 2014).

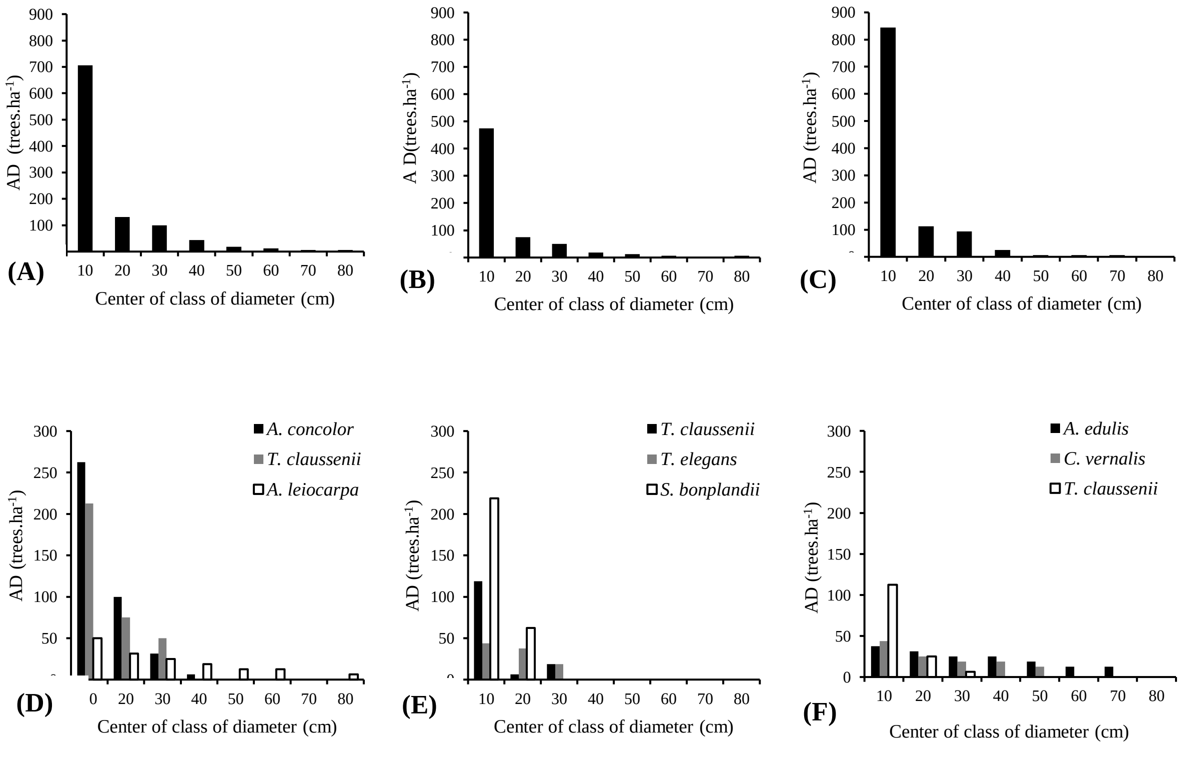

Figure 3 - Distribution of absolute density in the diametrical classes for the arboreal component, of Cluster I (A), Cluster II (B) and Cluster III (C); and of the main species of Cluster I (D), Cluster II (E) and Cluster III (F) of a remnant of Subtropical Seasonal Forest, Nova Palma, RS, 2013, in which: AD: absolute density (trees.ha^{-1}); DBH: diameter at the breast height.

The species *T. claussenii* and *A. concolor* showed diametrical distribution more similar to negative exponential distribution, a condition that affirms the need for maintenance of these plants in the forest in the near future. However, *A. edulis* did not present negative exponential distribution, having low representation of individuals with lower DBH, which evinces the instability of the population (Durigan 1998). In this case, the tendency is the reduction of individuals or even the disappearance of the population of *A. edulis*. This condition could be caused by the lower resources of propagules of this species in Cluster III sites and/or by the difficulty that seedlings have in becoming established due to the soil conditions, and by the fact that the seeds have a recalcitrant behavior (Lorenzi 1998; Carvalho 2006).

When considering the three floristic clusters, we can infer that Cluster I presented structure and floristic composition nearer to mature forest (primary forest). This is attributed mainly to this cluster having the greatest number of species and the most developed phytosociological structure of late secondary species, whereas in Cluster III, there was the presence of initial secondary species.

Conclusions

The cluster analysis showed the presence of three distinct Foristic groups indicating the need for differentiated interventions in the forest

The Foristic groups were influenced by aspects of the occupation history of the area, succession stage and edge effect in the remmant.

Group 1 has the highest values of diversity and number of species between the groups and the highest floristic similarity with the forest in general, being considered the closest representative of the floristic composition of the forest remnant Subtropical Seasonal Forests evaluated.

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